Evaluation of Electronic Documents for Preparing Naval Meteorological and Oceanographic Briefings

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Introduction: Naval meteorological and oceanographic (MetOc) personnel provide weather information and forecasts to aircraft, ships, and land-based components of the Navy. They are called on frequently to prepare briefs that describe the impact of weather on naval operations. The MetOc personnel studied in this research estimated that they each gave an average of 144 briefings annually. With the work demands they face, MetOc personnel must have systems that are quick and easy to use. For decades, the Navy has produced a number of paper products that provide historical meteorological, oceanographic, and geophysical information about specific geographical areas. The documents include charts on winds, tides, rain, currents, temperature, sediments, and biology. In line with its goal of moving to computerized work processes, the Navy has been developing computer-based alternatives to these paper documents. This study evaluates two of these alternatives, comparing them to traditional paper documents. These two alternatives are web hosting a version of the paper document (WEB_PAP), and a user-centric electronic document (UC-CD) hosted on a CDROM.[1] The design objectives of this product (Fig. 1), the Digital METOC Acoustic Reference Manual, are to: (1) link all the parts of the product into one cohesive whole; (2) provide branching for quick access to any information; and (3) support the preparation of weather briefings by including digital cut/copy operations to move information into a briefing document.

Evaluation Approach: Our study compared the use of the traditional document (PAPER) to the two alternatives (WEB_PAP, UC-CD) in completing several tasks.[2] This included finding information about a location in the Persian Gulf, interpreting the information, and assembling the information into a briefing (Task1), as well as answering four specific questions (Tasks 2-5). Twelve personnel from MetOc units participated. They were familiarized with each document prior to using it for the tasks. Data included the time to complete the tasks, as well as time spent in the following subtasks: *Browse* for information; *Interpret* information; *Compose/edit* the briefing (Task 1 only); *Copy/paste* material from the MetOc document into the briefing (Task 1 only).

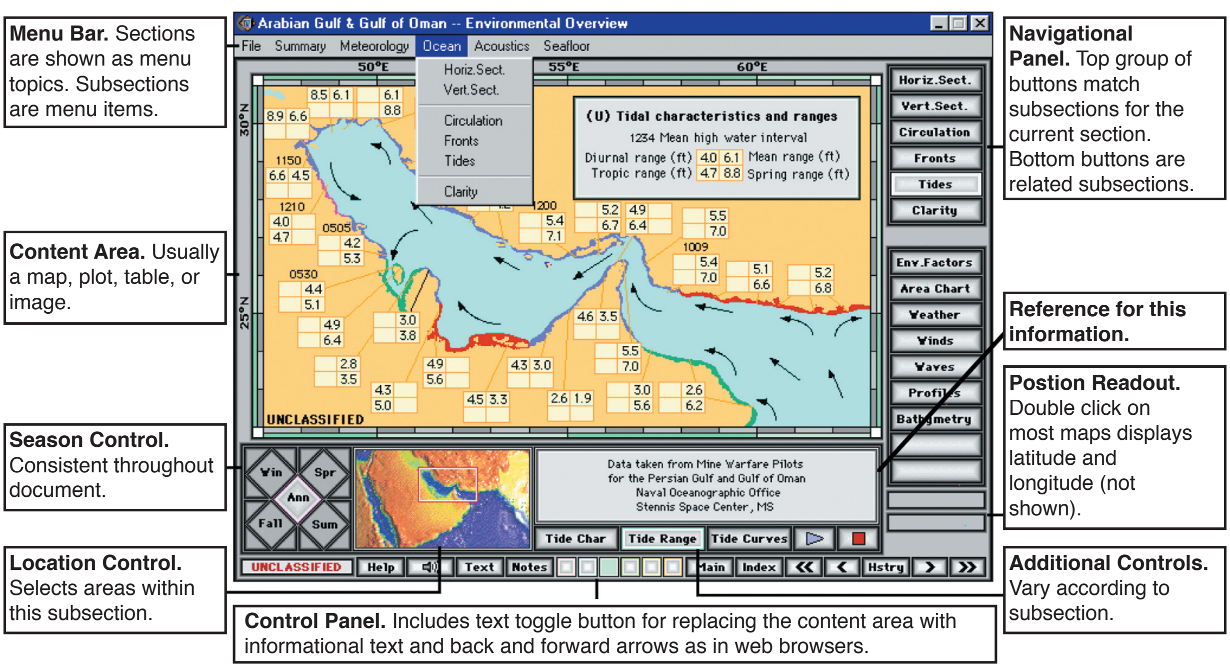

FIGURE 1
A typical DMARS screen with functional descriptions of the main sections. The section borders are highlighted in this illustration.

Results: The key result is that browsing for information to prepare a briefing (Task 1) was significantly slower with the WEB_PAP than with either the PAPER or the UC-CD (Fig. 2). It also took longer to answer a question about tides using the WEB_PAP. The main advantage of the PAPER and UC-CD documents on these two tasks was probably the ability to quickly scan the information in the entire document and glance at images. This was done by flipping pages in the PAPER, and with the menu and navigation bars in the UC-CD, as illustrated in Fig. 1.

However, answering a question about fishing activity (Task 3), by using the UC-CD was slower. This result was probably due to the UC-CD menu design, which placed Fishing Activity as an element on the menu entitled "Human Activities." In the other documents, fishing activity was listed as a separate topic in the table of contents. Thus, details of menu design are critical to performance on electronic documents. The results on Task 5, determining the duration of daylight at a particular location for a particular date, showed both the benefits and limitations of the UC-CD design. Using the PAPER or WEB_PAP documents, the subjects had to interpret the graph illustrated in Fig. 3. With the UC-CD, the subjects were significantly faster

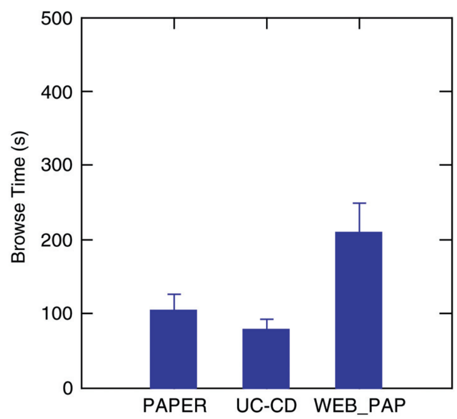

FIGURE 2
Average browse time in seconds by document type for Task 1, preparing a briefing. Standard error bars illustrate the variance of the average.

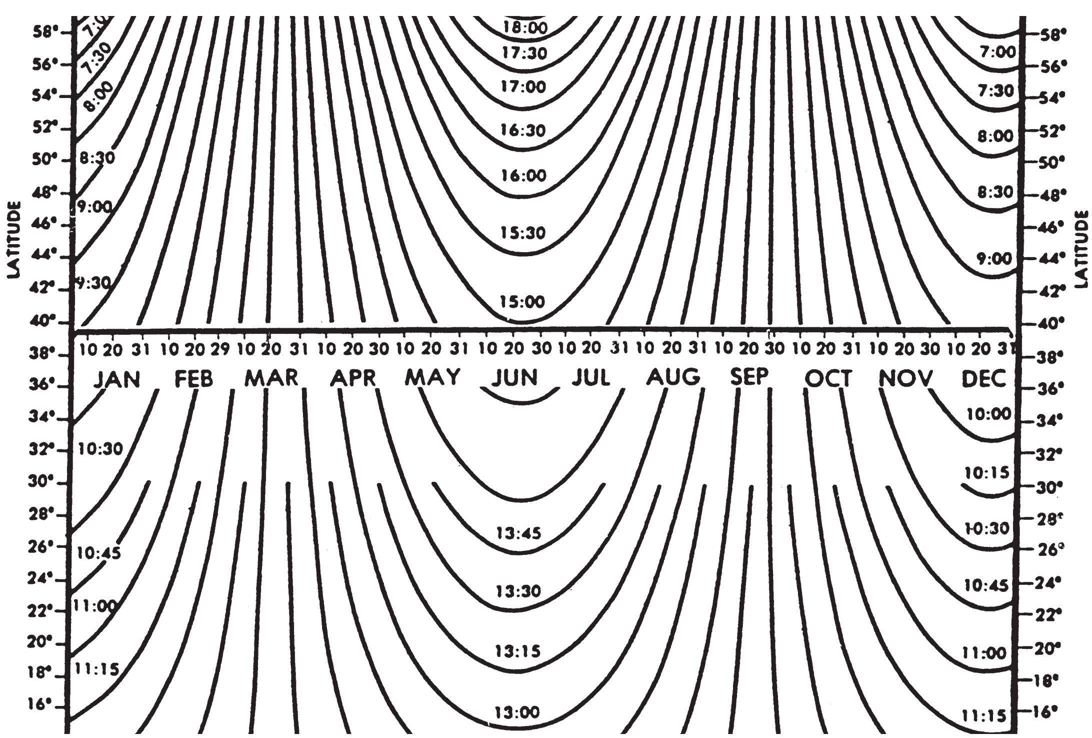

FIGURE 3
Illustration of how daylight data were presented in the PAPER and WEB_PAP documents.

because they simply had to select a geographic location on the map, select a date from a calendar, and read the daylight duration. However, there were more errors with the UC-CD because the subjects sometimes neglected to select a location on the map. This type of error can be eliminated by a redesign of the interface to prompt for a map selection. Finally, we found that more images were incorporated into the briefing when the UC-CD was used, and the subjects preferred this document to the other two.

The design approach used to produce the UC-CD clearly paid off. The images were designed to be readable on the computer, to have a consistent map across different types of data, and to be informative and appealing. In addition, the interface and its controls were designed to be consistent and intuitive. Overall, our research provides a compelling case that electronic documents should be developed with a user-centric design approach.

Acknowledgments: Our thanks to LCDR Bill Nisley II, CDR Chris Gunderson, and LCDR Roy Ledesma for coordinating the subjects and facilities.

[Sponsored by ONR]

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Satellite Networking for Naval Battlegroups

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ITT

Introduction: The Information Technology Division at NRL continues to advance the satellite networking capabilities of Naval battlegroup networks. Combat systems of the future have been set up to interact with a number of sensors, systems, and collaborative tools from within the Navy and from the other services. This requires a sophisticated battlegroup network to provide both the capacity and the flexibility necessary to support this integration. The primary backbone of this network-centric warfare scenario is a set of satellite-based links between a primary, or "hub," command ship and a number of other ships in the battlegroup, as well as to resources ashore.

Satellite-based Networks for the Fleet: Operation over a satellite transponder provides high-data-rate channels between distant terminals on land or at sea. However, the latency introduced by such a link (~0.25 seconds from one Earth station to another via satellite) can have severe implications on network operations.

In addition, there is a critical shortage of space for new antenna systems aboard U.S. Naval combatants. Each new system added must ensure that it neither creates nor is impacted by electromagnetic interference (EMI) while used in conjunction with operational shipboard systems.

The Satellite and Wireless Networking Section, Code 5554, develops methods, hardware, and architectures to support high-data-rate networks for the fleet. Electronics engineers and computer scientists collaborate with Naval staff and other laboratories to create solutions that link applications within a platform to other combatants at sea and on land. This is particularly necessary for small-deck combatants, which are currently lacking in connectivity and in available bandwidth for communications.

Fleet Battle Experiments: The purpose of the Navy's Fleet Battle Experiment (FBE) program is to "operationalize" network-centric operations and warfare. This is accomplished by developing a network-centric architecture that includes operational forces and infrastructure, providing those forces with wide-area network connectivity within the area of operation and a networked reachback capability. State-of-the-art combat systems applications, hardware, and communications technologies are applied to meet the architecture requirements. This effectively pairs networking and information technology with effects-based operations to achieve the full impact of coordinated network-centric warfare. FBE seeks to experiment within the operational and tactical level of war, focusing on the seaward concepts and procedures in support of maneuvering and time-critical targeting.

Fleet Battle Experiment—India: NRL successfully developed and implemented an advanced shipboard network to support the Navy Warfare Development Command during Fleet Battle Experiment-India (FBE-I) in June 2001. NRL provided a high-data-rate (HDR) networked connectivity between four Naval ships and two land sites, with the hub aboard the Third Fleet flag ship, the USS *Coronado* (AGF-

11) (Fig. 4). The ships involved were the USS *Bunker Hill* (CG-47), the USS *Lake Champlain* (CG-52), the USS *Bonhomme Richard* (LHD-6), and the USS *Stennis* (CVN-74). The land sites were the Fleet Command Training Center, Pacific (FCTCPAC), San Diego, and Camp Pendelton, California. Four of the ships, including the flagship *Coronado*, were each equipped with commercial Ku-band shipboard antenna systems with special EMI protection developed for Naval platforms. The carrier, the USS *Stennis*, was in port for the entire exercise, and was supported using a fixed 2.4-m antenna system identical to that used at FCTCPAC. The NRL-installed Ku-band satellite communication (SATCOM) systems provided the six sites at sea and on land with full duplex links to the USS *Coronado*. The data rates for each link ranged from 512 kbps to 4 Mbps full duplex, for a total aggregate throughput of 14 Mbps for the exercise.

NRL's network allowed FBE-I to exercise advanced sensor-to-shooter concepts and to extend high bandwidth SIPRNET (Secret Internet Protocol Routing Network) to the five ships afloat and to Camp Pendelton on shore. Advanced video, data, and voice products were transported successfully across the entire network. FBE-I operated for the first time with its hub and Network Control Center (NCC) at sea with the battlegroup, and the entire exercise was run and coordinated from the *Coronado*. An NRL-designed control system was implemented to support link reconfiguration of all nodes from the hub. These allowed the networks to be monitored and modified by NRL engineers during the exercise as warranted by the experimentation.

Conclusions and Future Developments: FBE-India successfully demonstrated the possibilities for commercial SATCOM augmentation of fleet operations in littoral areas and demonstrated the opportunities possible by establishing an at-sea control center in theater (Fig. 5). Shipboard SATCOM systems supported the experiment without adversely affecting normal operational performance or ship safety.

Based on this success (and on previous FBEs supported by NRL), Code 5554 will once again be the network and communication leads for FBE-Juliet/Millennium Challenge 02, which will take place in July-August of 2002. The operational network will again center on a battlegroup afloat, with the addition of a second satellite-based network to support network-centric warfare operations between the Navy and the other services.

NRL was also selected to design and implement the C4I space for the Joint Venture (HSV-X1), an experimental high-speed catamaran leased by both the Navy and Army to explore the operational capabilities of such a ship. NRL is installing a state-of-the-art C4I suite that incorporates both satellite and line-of-sight connectivity. This suite will support both standard fleet and Army communications channels, as well as advanced data/voice/video applications. Joint Venture is slated to participate in FBE-Juliet, among a number of other exercises in the U.S. and abroad.

Acknowledgments: The design, development, installation, and support of the FBE-India Communications Network was a major effort requiring signifi-

FIGURE 4
NRL installed high-data-rate SATCOM equipment like the antenna shown here on four Navy ships and two shore sites for FBE-India.

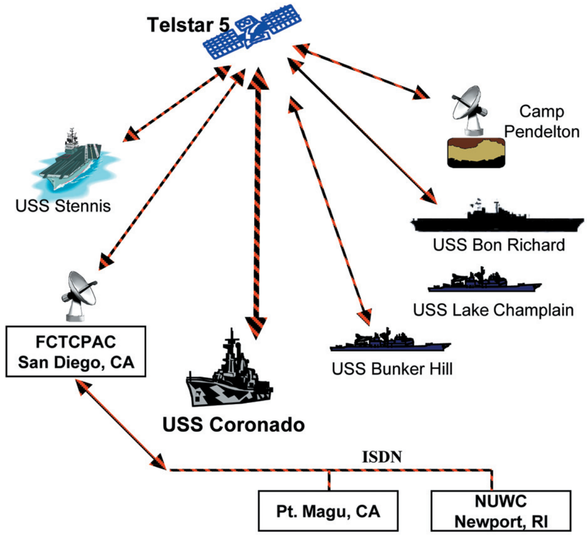

FIGURE 5
Satellite connections for the battlegroup network to support Fleet Battle Experiment-India in June 2001, operating off the coast of San Diego, California.

cant support from the Navy Warfare Development Center (NWDC) in Newport, Rhode Island. Contractors involved in the effort included ITT, BBN Technologies, and Scientific and Engineering Solutions, Inc. Also participating in this effort was the Naval Surface Warfare Center (Dahlgren, Virginia) and SPAWAR, San Diego. California.

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Advanced Visualization for Test and Evaluation and Training Ranges

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Background: By leveraging the rapid advances in computer graphics technology, the Tactical Electronic Warfare Division has researched advanced visual display concepts for improving the understanding of the integrated battlespace. For the Office of Naval Research (ONR), successful 6.2 and 6.3 projects were executed to explore, prototype, and transition an advanced three-dimensional display and analysis toolset known as SIMDIS. Under the ONR programs and with support from other Navy sponsors, the SIMDIS prototype toolset has matured and transitioned to a number of Navy test and training ranges, Fleet users, laboratories, and Warfare Centers.

SIMDIS is currently in operational use at several Navy and DOD ranges. It has gained acceptance as a tool that can rapidly improve an organization's analysis and display capabilities. The use of the SIMDIS toolset has continued to grow rapidly across the Navy and DOD, with more than 300 current users.

What is SIMDIS? SIMDIS is a set of software tools that provide two- and three-dimensional interactive graphical and video display of live and post-processed simulation, test, and operational data. The SIMDIS toolset is government off-the-shelf (GOTS) software that has been developed into a professional-quality software product. SIMDIS is supported, maintains file compatibility, and has an identical look and feel on multiple computer platforms. These include Silicon Graphics and Sun workstations, and PC workstations running Windows98, WindowsNT, WindowsME, Windows2000, WindowsXP, and Linux. SIMDIS does not require any commercial licenses to run, allowing visual playbacks to be easily shared with others and run on inexpensive PCs to high-end workstations.

SIMDIS provides a powerful capability for interactively visualizing and analyzing simulation and live data from any viewpoint, i.e., from different platforms/sites or specified location. SIMDIS provides a three-dimensional display of the normally "seen" data such as platform position and orientation as well as the "unseen" data such as the interactions of sensor systems with targets, countermeasures, and the environment. SIMDIS also provides tools for interactively analyzing data using custom tools for displaying equipment modes, spatial grids, ranges, angles, and antenna patterns. SIMDIS provides the capability to view time-synchronized 2D, 3D, and digital videos on a single standalone workstation or across multiple networked platforms. Figure 6 summarizes the SIMDIS Toolset capabilities.

SIMDIS Use at Test and Evaluation and Training Ranges: SIMDIS toolset capabilities as a real-time and a post-processing tool work well to support the needs of the Navy's ranges and Fleet. Figure 7 highlights some of its key features.

At the Southern California Off-Shore Range (SCORE), which supports Navy training for undersea, surface, and air missions. SIMDIS is used heavily in two areas:

1. Exercise Control—displays real-time tracks from the Range Operation Center's live data stream or from an NCTS Portable Range. This allows the Navy/Marine command and control elements to monitor the progress of an exercise.
2. Debrief Tool—records and then plays back an exercise for a participating unit. Key uses have

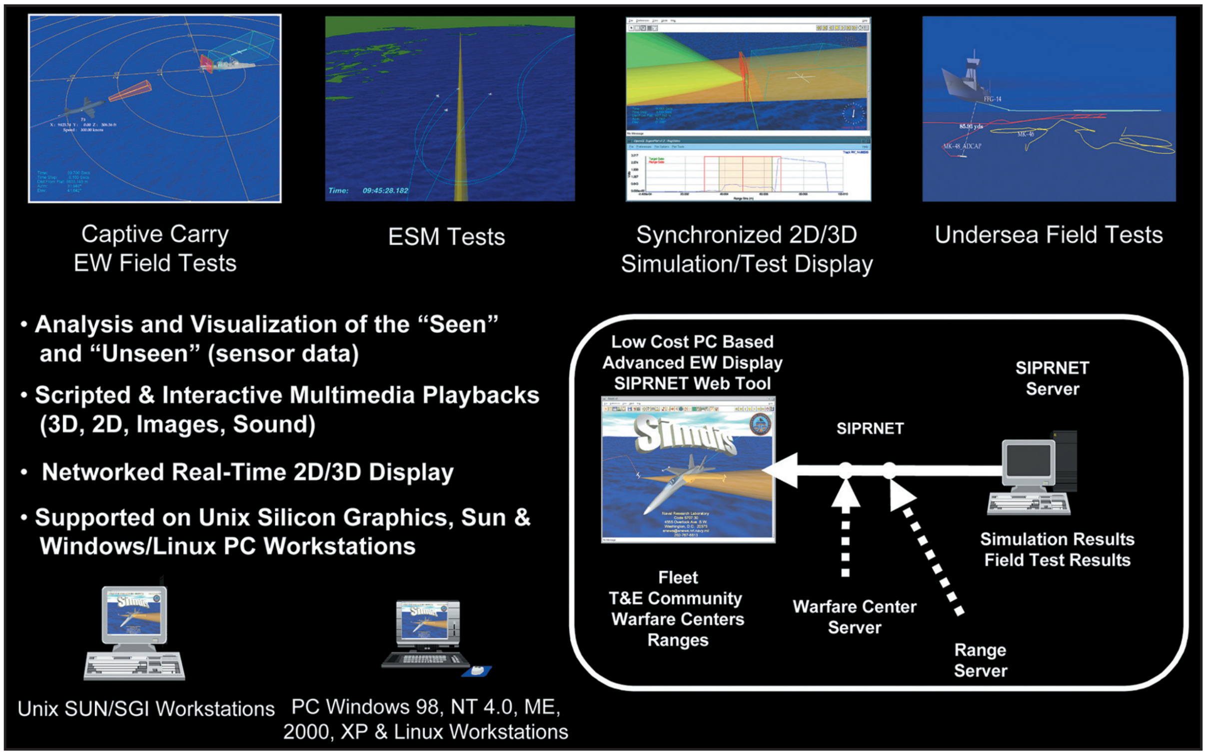

FIGURE 6
SIMDIS—Transitioning to the T&E, training, and operational communities.

FIGURE 7
SIMDIS toolset for T&E and training ranges.

been for the submarine and Tactical Air Command (TACAIR) (F-14/F-18) communities, which benefit from the high-fidelity 3-D displays. SCORE has also made heavy use of SIMDIS for debriefings of recent PACFLT JTFEX and COMPTUEX training exercises. PACFLT is working to enable the live SCORE feed to be available to the Fleet over the secure network for live display using SIMDIS.

At the Pacific Missile Range Facility, SIMDIS is used to support both training and test and evaluation missions. SIMDIS is used in the following areas:

1. Exercise Control—displays real-time tracks from PMRF's Instrumentation Network (INET) to allow command and control elements to gain improved situational awareness during the test.
2. Range Safety—used as a real-time decision support tool by the missile flight safety officers for missile and target firings. In this capacity, SIMDIS, through its INET interface, works with the Range Risk Analysis Tool (RRAT) model to calculate and display real-time risk values and flash appropriate visual warnings when necessary.
3. VIP Display—used during high-profile tests to produce live integrated test mission displays for both local and remote viewing.
4. Debrief Tool—records live data streams during a test and is used to provide rapid visual playbacks for after-action quick-look data/test reviews. SIMDIS is also used for analysis purposes by calculating and displaying preliminary measures of effectiveness (MOEs), such as miss distances, etc. In addition, SIMDIS 3D playbacks are integrated with digital video files within a few hours of the test, and a detailed multimedia scripted playback is produced for mission data reviews.
5. Data Product—SIMDIS playback data files are also available as a standard data product from PMRF. Both test and training users of the range receive the integrated visual playbacks of their tests.

At other facilities, such as the Naval Air Warfare Center Weapons Division, Echo Range, at China Lake, California, SIMDIS is used for post-processing analysis and display. Figure 8 shows a representative SIMDIS display of target tracking radars vs ground truth.

Summary: SIMDIS is a powerful way to integrate multiple types of data for both live and post-processing analysis and display. The SIMDIS toolset success builds off of recent advances in graphics processing technology and provides concrete payoffs to DOD test and evaluation and training ranges, operational users, and others. The SIMDIS toolset demonstrates that a well-executed GOTS software development model can be very effective in rapidly transitioning simulation research into the Navy/DOD community.

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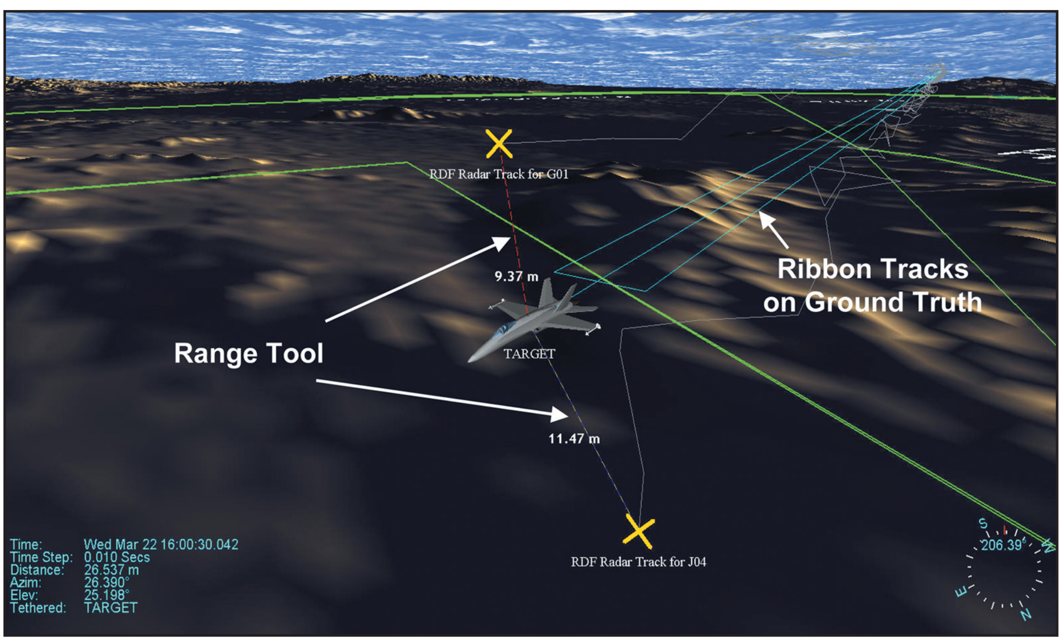

FIGURE 8
Visual analysis of test data.

Signal Sorter for Advanced Multifunction Radio Frequency Concept (AMRF-C) Using Neural Networks and Advanced Statistical Techniques

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We describe an artificial intelligence (AI)-based electronic surveillance processing signal sorter currently being developed for AMRF-C that uses emitter characteristics as its input. It has been evaluated on two different data sets. The clustering quality and the processing time were found to be comparable to that achieved by experienced human analysts.

AMRF-C is an Office of Naval Research program that addresses the increasing challenges of shipboard topside RF functions, Electronic Warfare (EW), radar, and RF communications, in the context of a proof-of-concept demonstration, sharing a common receive and transmit antenna (Fig. 9). Each antenna uses phased-array technology organized into software-programmable subarray apertures that can be dynamically allocated to selected combinations of EW, radar or communications functions. The initial AMRF-C demonstration covers the broad frequency range of H, I, and J bands. It requires broadband Electronic Support (ES) receiver assets to provide the timely warning and surveillance necessary for ship-self protection. EW includes ES passive receive functions and the Electronic Attack (EA) active countermeasures transmit function.

Electronic Warfare Support (ES) Functions: In the AMRF-C demonstration, ES performs two functions, High Probability of Intercept (HPOI) and High Gain High Sensitivity (HGHS) and uses state-of-the-art Wideband Digital Channelized Receiver System (WBDCRS) technology. Figure 10 illustrates the ES functional hardware. HPOI uses nine dedicated elements in the receive array to perform pulsed radar intercept, which includes a bearing measurement obtained using interferometric techniques. State-of-the-art downconverters and fiber optic links process and transmit each analog radar pulse to the WBDCRS for digital conversion and Pulse Descriptor (PD) records-generation, for subsequent HPOI software processing. HGHS uses a state-of-the-art digital beamformer and a fast Fourier transform processor to convert the radar pulse energy collected over the entire phased array into both time-domain and frequency-domain digital data streams. Radar pulses in the time domain are converted into PD records. Frequency domain data are processed to detect LPI radar.

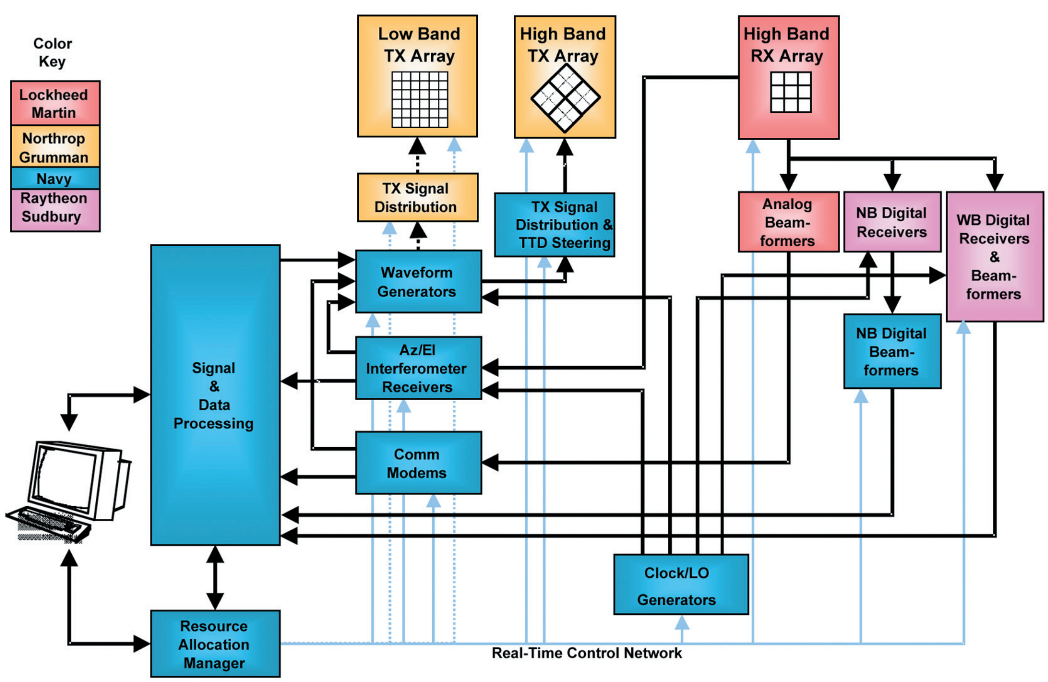

FIGURE 9
AMRF-C concept testbed architecture.

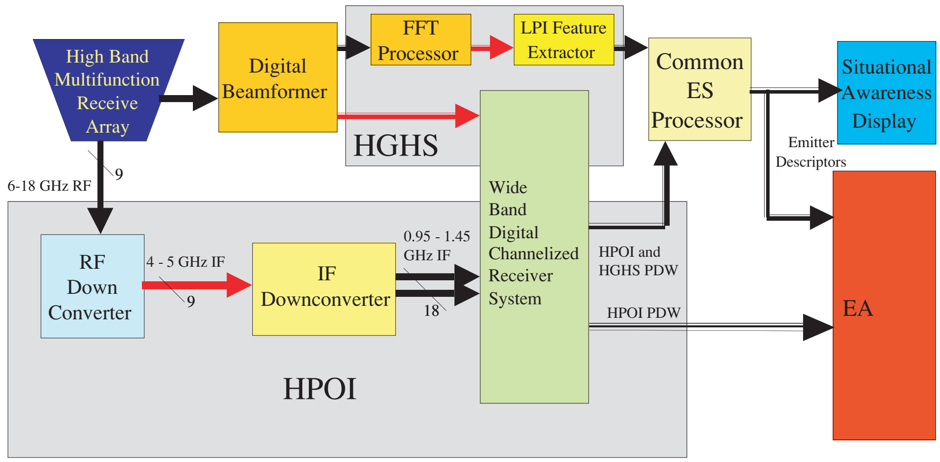

FIGURE 10
Electronic surveillance functions in AMRFC.

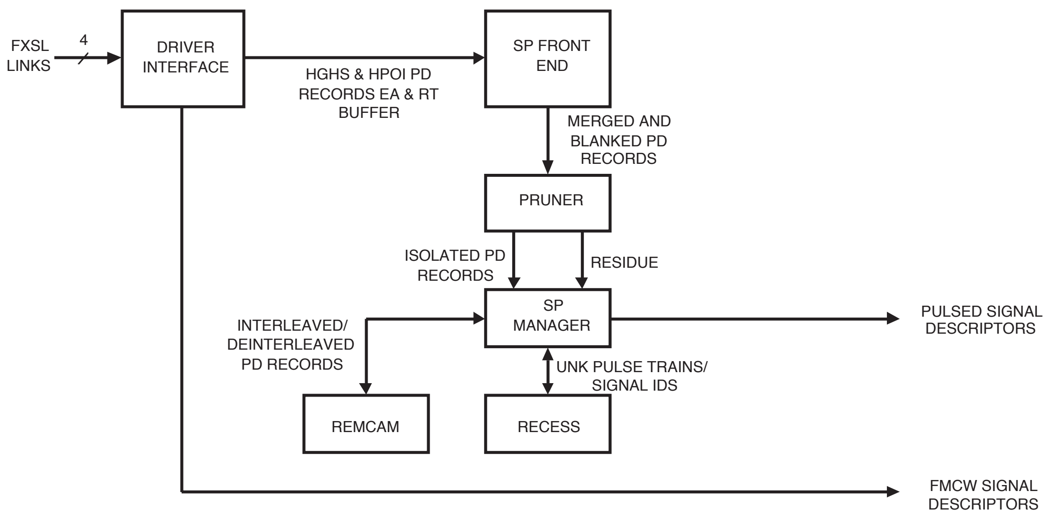

FIGURE 11
Signal processing signal flow.

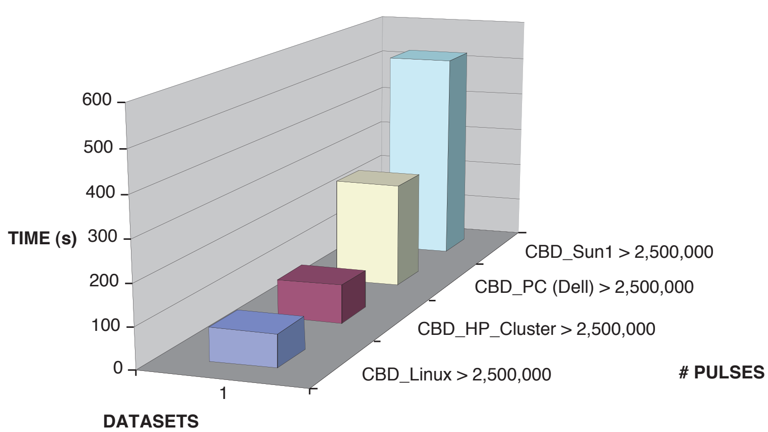

FIGURE 12
Evaluation of pruner processing time on four systems.

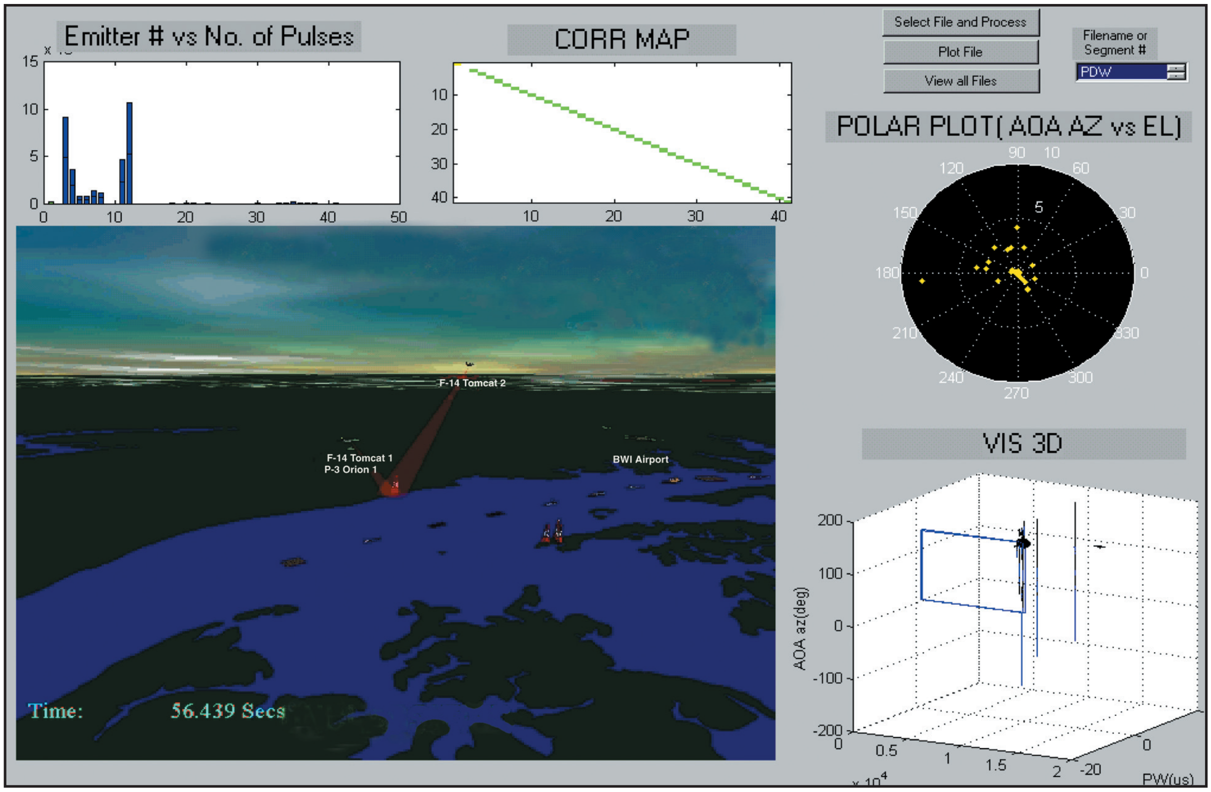

FIGURE 13
Simulated scenario.

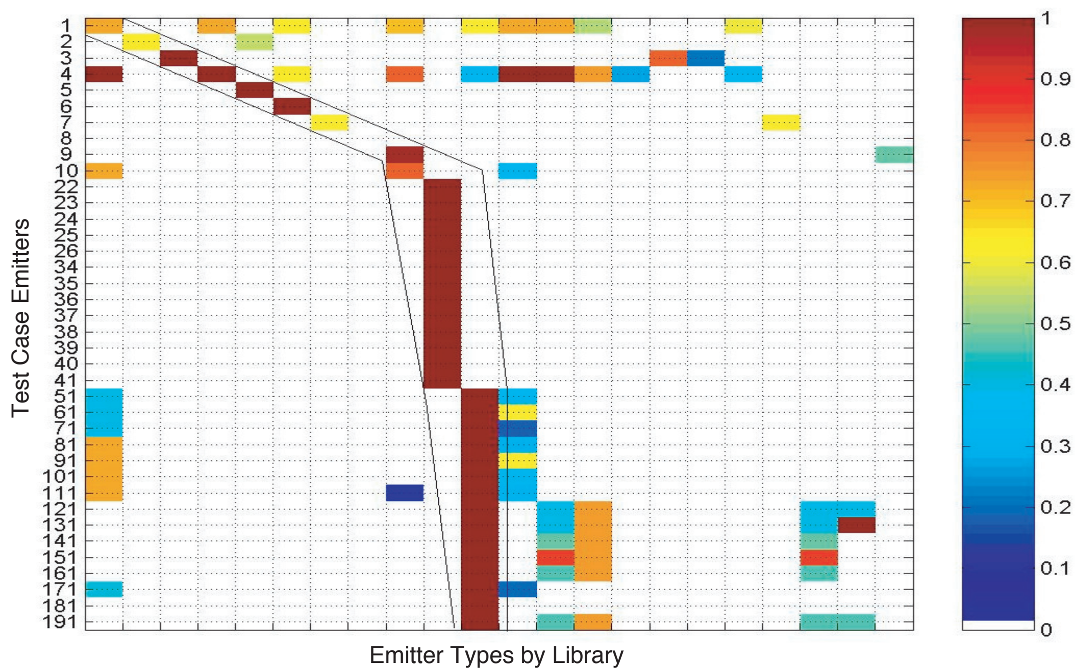

FIGURE 14
Plausibility description from RECESS.

ES Signal Sorter (SS) Components: Electronic Warfare Support Measures (ESM) includes collection and analysis of radar signals. A typical environment may contain multiple signals with pulses from one emitter interleaved with pulses from others. In baseline systems, pulses are collected, processed, and then deinterleaved into their separate pulse trains. The AMRF-C SS module receives Pulse Descriptors (PD) into a modular AI-based electronic surveillance processor. The ES Signal Sorter (Fig. 11) contains several artificial neural network (NN) components: the Pruner, a rapid statistical signal sorter; the Signal Processing (SP) Manager; the NN Toolbox, Rapid Emitter Multiple Clustering Algorithm (REMCAM); and the Correlator, Rapid Emitter Clustering Expert System Software (RECESS).

Pruner: The Pruner isolates and extracts the well-behaved PD records from the interleaved incoming stream. It is a fast, computationally efficient module that is used in the first-stage sorting process. Figure 12 shows the Pruner module processing time for a simulated 2.5 million pulses from a typical AMRF-C scenario (Fig. 13) on different systems. The Pruner module passes the isolated signal descriptors and the residue PD records to the SP Manager. The SP Manager controls the overall data flow. It first directs the interleaved residue to the NN-based REMCAM for deinterleaving. It then passes the isolated PD records to the library correlator (RECESS) for identification. Finally, it reports situational awareness (SA) information to an ESM functional graphical user interface.

Neural Network Toolbox (REMCAM): The AMRF-C REMCAM process uses four NN clustering algorithms and isolates PD records from the residue submitted by the SP Manager. Seven clustering algorithms have been evaluated for REMCAM; the optimal four are to be inserted. They are: Cellular Network Classifier (CNC), Fuzzy Adaptive Resonant Theory (FA), K-Means, Learning Vector Quantization (LVQ), Radial Basis Function (RBF), Self-Organizing Feature Maps (SOFM), and Supervised Piriform Hierarchical Clusterer (SuperPHC). Each algorithm outputs a matrix of binned pulses that form labeled pulse trains. The outputs are combined, and a consensus report of the residue analysis is transmitted to RECESS via the SP Manager for identification.

Expert System (RECESS): RECESS implements Dempster-Shafer reasoning to associate the isolated PD records to emitter types. It correlates received radar pulses with single emitting sources (i.e., isolated PD records), uses the pulse information to measure characteristic parameters of the source, uses the measured parameters to identify the source against an emitter library, and correlates emitters to their platforms. RECESS provides a plausibility ranking showing the likelihood that an emitter is any one of the library types present in the scenario. Figure 14 depicts the classification of the isolated PD records to the emitter types. The SP Manager uses the plausibility reports to decimate the emitter types in the situational awareness report (highlighted structures).

Summary: This program demonstrates the use of advanced automation techniques to perform real-time ES functions in an integrated modern RF system including EW and communications. Use of such enabling technologies supports the Navy mission in reducing emitter ambiguities and processing complex tasks. Modern EW/ES systems will increasingly use the AI-based technology demonstrated here in integrated systems such as AMRF-C and become commonplace.

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